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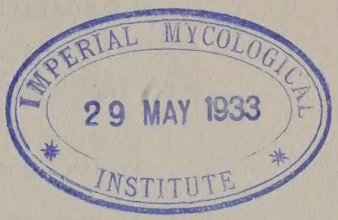

PURDUE UNIVERSITY.

BULLETIN

OF THE

AGRICULTURAL EXPERIMENT STATION

OF

INDIANA.

SMUT OF WHEAT AND OATS. J. C. ARTHUR.

SEPTEMBER, 1889.

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SMUT OF WHEAT AND OATS.

There are two well-defined kinds of smut in cereals: one in which the head is mostly changed to a black dust, and another which shows only upon the kernel being broken open, when the usual contents are found to be replaced by a black unctious powder. Although these two kinds are quite as distinct in relationship as in habit, and are readily distinguishable by every one, the same common name is usually made to do service for both.

One of the first requisites in acquiring and communicating exact knowledge is accuracy of the terms employed, and therefore I shall use qualifying words to distinguish these two smuts. In their selection I have followed what appears to be the usage of this country, so far as there can be said to be any usage at all, and one which is sanctioned by so good an authority as Dr. Bessey* of Nebraska, and that is to call the one covering the heads with a powder, the "black" smut, and the one confined to the kernels the "stinking" smut. The latter is known as bunt in England.

It is to the latter that this bulletin is mostly devoted, and is issued especially to meet the demand for information in the northern part of Indiana, where there has been a very unusual loss of wheat in the crop just harvested on account of this smut.

STINKING SMUT.†

The name fetid smut would be more pleasing, but the one adopted is good English and fitly describes a very noticeable characteristic. A strong and disagreeable odor, not unlike that of rotten eggs, is exhaled from the crushed berry when fresh, and may be detected at the time the grain is ripening many rods from an infested field, especially in the evening or when the air is moist.

Amount of Loss.—As a rule this is not an abundant fungus, but it occasionally becomes prominent in more or less restricted localities, as if epidemic, and in such cases the loss ranges from a small per cent. to nearly the total crop. A case in point is the one which attracted the attention of the Station staff a few weeks ago and the investigation of which has resulted in the publication of the present bulletin.

The Haw Patch is a region with rich loamy soil and gravelly sub-soil in LaGrange county in the northeastern part of Indiana. No more uniformly thrifty and enterprising farmers can be found

* Bulletin of Iowa Agricultural College, 1884, pp. 119, 123.

† Specimens of wheat heads affected with stinking smut accompany part of the edition of this Bulletin, being sent especially to the farmers of Indiana.

in the State, and any controllable pest among them is not likely to be tolerated after the method of extermination is known. A handful of wheat brought from the region, taken from a field at random, showed over half the heads filled with stinking smut, and in view of this fact a further personal examination of the field and of others in the vicinity was deemed advisable.

I arrived in the Haw Patch on July 16th and spent two days in examining the grain fields. I desire at once to express my indebtedness and that of the Station to the assistance and kindness of Mr. J. N. Babcock and Mr. J. N. Latta, who gave me every facility for gathering information, Mr. Latta devoting his whole time to the matter.

The first field visited was one of about twenty acres, and the one probably most affected of any in the immediate vicinity. It was harvested and in the shock, and to all appearance was a good crop. The first handful of heads taken at random gave nineteen sound ones and twenty-five filled with smut; that is a loss of 56.82 per cent., a proportion that cursory examination in other parts of the field appeared to sustain. The heads of a bundle taken without selection were separated as they came to hand and gave 210 sound and 245 affected ones, a loss of 53.84 per cent.

Two other bundles were taken; some care being exercised that they should be a fair sample of the crop, although the examination showed that the variation in different parts of the field was not great. One bundle contained 3200 heads, and the other 2596, of which 3028 heads, counting the two together, were smutted or 52.24 per cent. One may therefore conclude that over half of the crop was actually lost on account of the smut in it.

In fields adjoining this one the crop was for the most part in normal condition. Other fields in the vicinity, however, were reported quite as bad as the one seen, but these were not examined.

All these fields, so far as ascertained, were sown with seed obtained directly or indirectly from the farm first visited, and it was learned that the grain was so badly mixed with stinking smut the year previous that the millers had objected to grinding it, but no one had thought of refusing it for seed wheat. Inquiry elicited the information that there were two or three other centers of infection in neighborhoods several miles distant in different directions.

This is not the first appearance of the disease in the State or in the country, although former outbreaks have not attracted wide attention. Mr. Wm. Poyser, of the Haw Patch, a most intelligent and thrifty farmer, says that he distinctly remembers a similarly abundant occurrence of the smut in the same region fully thirty years ago. It is undoubtedly more common in the Mississippi Valley and in California than on the Atlantic side of the Continent.

In Europe it has been known much longer than in this country, and especially during the last century considerable has been written on the subject. A very accurate German agricultural writer* says: "I myself have seen in the vicinity of Halle as well as in the fertile region about Ratibor two fields of peasant holdings in which 30 to 50 and possibly a still higher per cent. of the wheat heads were destroyed by Tilletia" (stinking smut). A well-known writer† in England says: "we may sometimes see a crop injured to the extent of one-third or more."

Since the visit to Haw Patch the writer has learned of several instances of injury to the wheat crop by stinking smut in other parts of the State during former years, and also in adjoining States.

Enough has been said, we think, regarding the possible and the actual loss from stinking smut to make it desirable to give some further descriprion of the parasite which causes the injury, and of its mode of action.

Description of the Fungus: The injury is done by a fungus, that is by a vegetable parasite belonging to a low order of plant life. It begins to grow at the time the wheat starts from the grain, and in order to maintain its life, must shortly find its way into the interior of the wheat plant. Once inside the young plant it grows as the wheat grows, passing up through the stem to the very top. When the wheat forms its reproductive bodies (seeds) the fungus does the same, and curiously enough the reproductive bodies of the fungus (spores) are produced inside the reproductive bodies of the wheat, so that instead of the usual hard grains of wheat we find a soft mass of greasy blackish spores.

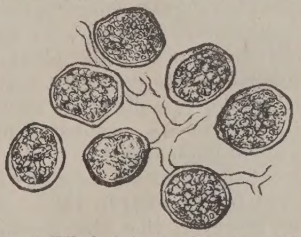


Fig. 1. Spores of stinking smut (Tilletia fœtens), with a branching filament of the fungus. × 480 diameters. Original.

If spores from a smutted grain are placed under a microscope, the black powder, as it appears to the naked eye, is resolved into innumerable rounded bodies, the individual spores, as shown in figure 1, and among them delicate branching threads to which the spores were once attached. The body of the fungus, which has grown up through the wheat stalk from the ground to the seed, is not

* Wolf, Krankheiten der landw. Nutzpflanzen, 1887, p. 58.

† Berkeley in Morton's Cyclopedia of Agriculture, 1856, Vol. 1, p. 368.

materially different from the branching filaments which support the spores (fig. 1), and consists of long, very delicate threads, quite colorless and transparent, and consequently very difficult to detect even with a good microscope. The nourishment for the fungus comes from the juices of the wheat plant in which it grows.

Early Opinions: The grain smuts were known in ancient times. Pliny and Theophrastus wrote about them and considered them due to untoward conditions of weather and soil, a view that was generally held up to the beginning of the present century, and by a few even much later. The black powder from the heads was considered the result of a morbid transformation of the tissues of the plant, and quite analogous to pathological changes in animals. In 1801 Persoon* described the stinking smut as a fungus, which greatly modified the accepted opinions regarding the nature of the disease. It was now thought by some that the fungus was a product of the diseased condition of the plant. This view was very fully stated by Meyen,† who wrote as late as 1841. Although well acquainted with the literature of the subject, and also with experiments in sowing smut with sound seed wheat, yet he‡ says: "Various botanists have expressed the opinion that smut comes from the soil in which the diseased plants grow, entering through the roots; some have imagined the thing very literally, for they assume that the smut spores themselves enter into the plant; the most, however, have represented the case quite correctly, viz: that only the substance of the smut powder in a dissolved condition enters into the plant from the soil, and the sap is affected in such a manner that the same disease is again engendered."

That the spores of the smut are capable of germination had already been discovered by Prevost‖ in 1807. It was not till about a half century after, however, that the germination was carefully studied, first by Tulasne,§ then in rapid succession by a number of eminent investigators. It has been thirty years since it was definitely proven that the fungus arising from the germinating smut spore actually enters the young wheat plant,¶ thereby starting the infection which results in a smutted head, although very good experiments were performed more than a century ago showing that if the wheat sown had smut spores adhering to it the crop would be smutted.**

* Persoon, Syn. Meth. Fungorum, 1801, p. 224.
† Meyen, Pflanzen-Pathologie, 1841, pp. 108-119.
‡ l. c., p. 113.
‖ Prevost, Mem. sur la cause immed. de la carie, 1807.
§ Ann. des Sci. Nat., 1854, T. ii.
¶ Kuehn, Krankheiten der Kulturgewæchse, 2d ed., 1859.
** Gleichen, Auserlesene mikrosk. Entdeckungen, 1781, p. 46; quoted from Meyen, l. c.

External Characters: Stinking smut is sharply distinguished from black smut, the only two smuts of wheat and oats, by its strong odor and inconspicuousness. It is not easily detected until harvest time. The affected wheat plant thrives about as usual, the head fills, and the chaff is distended as if with a normally plump grain. A close observer will notice, however, that already before wheat heads

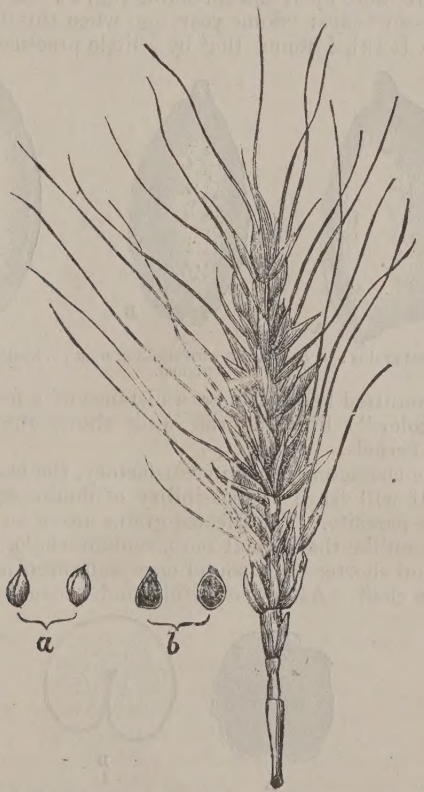


Fig. 2. Head of wheat affected with stinking smut: *a*, two smutted kernels: *b*, the same split open. Natural size. After Bessey.

out, the diseased plants have a darker green color and somewhat more luxuriant appearance. When the grain is only six inches high or so, this difference in appearance is quite striking, the affected plants being darker green and taller, as if droppings of manure had forced them to extra growth. The growth does not continue so long, however, as in the healthy plants, so that they do not usually

become so tall, and are premature in heading and in ripening up the leaves. The characteristics now become rather more evident. The affected heads retain a bluish-green or greenish-lead color for some time after the sound ones begin to ripen, and then take on a bleached appearance in strong contrast to the yellow of the sound heads; the heads being much lighter stand more erect; and the chaff and beard are more open and spreading (fig. 2). Relying upon these features, Bessey* says: "Some years ago when this disease was quite common [in Iowa], I found that by a little practice I could readily

FIG. 3. Wheat grains: *a*, *b*, diseased with stinking smut; *c*. healthy. × 5 diameters. Original.

detect the smutted heads even at a distance of a few yards by their form and color." Pinching the heads shows they are not filled with solid kernels.

If these characters prove unsatisfactory, the examination of the kernel itself will leave no possibility of doubt regarding the presence of the parasite. The affected grains are of an opaque greenish color, quite unlike the normal ones, remain whole, are considerably distended and shorter than sound ones and often project somewhat between the chaff. After harvesting and becoming well dried out

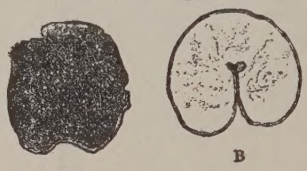


FIG. 4. Wheat grains cut across the middle: *a*, smutted grain, the irregular outline due to drying; *b*, sound grain showing the usual deep crease. In both grains the crease is on lower side. × 5 diameters. Original.

they are dull brown, and slightly shrivelled (fig. 3 *a*, *b*). The natural crease of the kernel is nearly obliterated (fig. 4 *a*).

Upon breaking the kernel open a blackish, or when compared with a really black object, dark brown, unctuous powder, of dis-

*L. c., p. 120.

agreeable odor when fresh, appears to have entirely replaced the germ and flour of the healthy kernel (fig. 4). There is an unpleasant sensation in finding that the labor of a season has resulted to however small extent in filling the grain heads with such an obnoxious black mass instead of good marketable grain.

NAME: The disease has always been known in this country, apparently, as simply "smut", or rarely as "stinking smut." In England it is also spoken of in the same way, but more commonly as "bunt," a word of long standing and obscure origin. It would be a decided gain if this term could find general acceptance in America, but there appears to be no present prospect of it.

The first person to name the fungus was the Scandinavian botanist, Bjerkander*, who called it Lycoperdon tritici. In 1854 Tulasne† published a fine memoir on the smuts and in it changed the name to Tilletia caries, to conform to a better classification. The latter name was at once adopted, and is still used by many writers. But there are certain laws of priority that all systematic botanists are bound to respect, and when the obscurely published name of Bjerkander was brought to their attention, it became necessary again to change the name, making it Tilletia tritici, which is now used by the best authorities‡ on the subject, and by their followers.

While making an extended practical study of the subject Kuehn§ discovered in 1867 a smooth-spored form of stinking smut, to which he gave a name and later published a description. He called it Tilletia lævis. The common form in Europe (T. tritici) has round, minutely roughened spores, the other form has rather larger, irregular, and entirely smooth spores; otherwise the two forms are apparently alike. Abroad the smooth form is mostly met with in the British Isles. In this country the smooth form appears to prevail almost to the exclusion of the other, and in both spring and winter wheat regions. It is the one found at Haw Patch, Ind., specimens of which are distributed with part of the edition of this bulletin. The two forms differing only in microscopic characters, may be treated for practical purposes as if the same.

It has lately come to light,‖ that in this case as in the other, the person first to name the fungus was not the one who first made it widely known. In 1860 the fifth and last volume of a set of dried fungi collected in South Carolina was published by Ravenel, with an edition of only thirty copies. It was in this work¶ that, so far as we know, the earliest name was first printed; in accordance therewith it should now read Tilletia fœtens.

*Act. suec., 1775, p. 326

†Mem. sur les Ustilag., 1854, p. 113.

‡Winter, Die Pilze, 1881, p. 110; Saccardo, Sylloge fungorum, VII. 1888, p. 481; Plowright, British Ured. and Ustil. 1889, p. 283.

§Hedwigia, 1873, p. 152.

‖Trelease, Parasitic fungi of Wisconsin, 1884, p. 35.

¶Ravenel, Fungi Caroliniani Exsiccati, V. 1860, No. 100.

Growth and Reproduction: The life history of the fungus is a comparatively simple one. The spores, forming the blackish powder of the affected kernels, when afforded the right degree of temperature and moisture, grow a short branched tube, from which other very small and delicate spores arise. These at once produce slender thread-like growths that enter the wheat plant just as it starts to sprout from the seed. Once within the wheat, it follows up the stalk inside until the time of flowering when it again fills the kernel with its black spores.

To be more particular, the spores form the smutted kernels, after being kept suitably moist for two or three days, send out a comparatively thick and short tube, which, if kept quite under water will continue to grow, and if it meets with a young wheat plant can enter it. But more commonly the growth from the spore is in moist air, or soon reaches it, and then from the end arise a number of slender tubes which form a sort of brush (fig. 5 *a*).

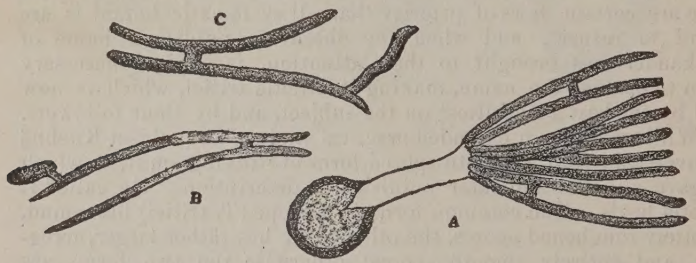


Fig. 5. Germination of spores of stinking smut: *a*, growth of smut spore in moist air, showing brush of long slender spores, partly united into H-forms; *b*, germination of an H-form spore in moist air, producing a different-shaped spore near one end; *c*, germination of H-form spore in water, forming tube near one end. × 500 diameters. After Wolff.

Part of these tubes unite into H-forms, finally ripen into independent spores, and becoming separated from the stalk on which they were produced, are free to be carried by the winds for distant infection. One can scarcely guess why they assume this H-form unless it be to anchor themselves when alighting upon rough or projecting surfaces. If these spores fall into water, they grow by sending out a tube (fig. 5 *c*) that may enter the wheat plant direct. In moist air they do not produce tubes but minute spores (fig. 5 *b*), which soon separate, and being extremely small may be carried by even slight movement of the air to very great distances. In a sufficiently moist place these will grow the usual filamentous tube for infection of the wheat plant, but if the situation is not moist enough for that kind of growth, the spore can renew itself by forming another spore of the same sort at one side, which permits of a new lease of life, and this in turn can form another, and so on. Eventually a filament is produced which enters the wheat plant, or else

the power for further development being exhausted the fungus perishes.

Whoever looks up this curious adaptation to avert unfavorable conditions during germination, should not fail to make himself acquainted with the contributions of Brefeld* to the elucidation of the subject. This investigator found that if any of the spore forms, either the original brown smut spores or any of the secondary forms, were kept submerged they produced only filaments and must necessarily soon find their way into the wheat plant or perish. But if the filaments reached the air, or the spore at first sprouted in moist air, a secondary spore was invariably produced. He also found that if the growing spores were kept in pure water the resulting filaments were short and soon became exhausted, but if in water containing nutriment, such as comes from decaying organic matter or the leeching of manure, the filaments continued to grow almost indefinitely, and might produce a mold-like mass quite visible to the naked eye. On reaching the air, however, they always formed spores again.

Attack and Spread of the Disease: We are now in a position to understand how the fungus attacks the wheat plant, and how it is distributed from field to field. These are some of the questions to be solved: Will the smut spread from field to field while the crop is growing, as rust does, and thus an affected field distribute the disease to the region all about in a single season? Will there be any danger of introducing it on one's farm by sowing seed wheat from a crop known to be smutted? Can the disease be introduced by the application of manure from a farm where it has already gained a foothold? When it once gets into the soil will it persist as milk-weed, quack-grass and Canada thistle do?

Whether the smut will spread from field to field, or even from a diseased plant to a healthy one growing beside it, must depend very much through what part of the plant the germinating spores effect their entrance and at what stage of growth. During an outbreak of the disease in Iowa in 1872 Bessey† examined a number of wheat stools and found that in eleven instances all the stalks from a single kernel (six having three each and five having two each) with only two doubtful exceptions had all the heads destroyed with smut. My own observation at the Haw Patch a few weeks since gave essentially the same result. From this we must conclude that the fungus entered the plant near the point of stooling, that is, at or below the surface of the ground, for if it had occurred higher up we should often find one stalk smutted while another on the same plant would be sound.

The exceptional cases where smutted and sound stalks occur in

*Bot. Untersuchungen ueber die Hefenpilze, 1883.

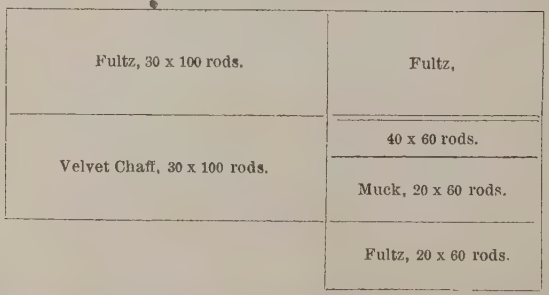
†L. c., p. 121.

the same stool, are to be explained in the same way as the occurrence of smutted and sound kernels in the same head, which was also found in a few instances at the Haw Patch by careful search. We are to suppose in these cases that by some accident of growth the fungus did not reach all parts of the plant or did not attain its usual full development.

But we are not dependent upon inferential knowledge for our information, direct observation* has shown that the spore threads enter the wheat plant at the time of germination, most readily along the edges were it is attached to the grain, and at any point above up to the first joint, sometimes called the tillering point. If the seed had any covering of soil to start with, this first joint will always be below the surface of the ground. It has been found impossible to infect the plant in other parts, chiefly for the reason, it is to be assumed, that the cuticle is nowhere else sufficiently tender to permit the delicate fungus growth to penetrate it.

It is easy to make a practical application of this piece of information. No infection can come to the wheat plant through the air unless the grain germinates lying upon the surface of the ground, and grains covered with soil can only receive infection from spores sown in contact with the seed. Therefore, the answer to our first question is, that stinking smut will not spread during the growing season, from field to field, or from plant to plant, to any appreciable extent. When wheat is thoroughly covered with earth by drill or harrow no infection can reach it that season, unless smut was sown with the seed or already existed in the soil.

This fact was well illustrated by a field on the farm of Mr. Latta, in which three varieties of wheat—Fultz, Velvet Chaff and Muck—were sown at the same time and in the same manner, side



by side, as shown in the accompanying diagram. A strip of Velvet Chaff only twenty-four feet wide (*a* in the diagram), made by two rounds of the seeder, passed through one of the plots of Fultz wheat.

* Kuehn, Krankheiten der Kulturgewæchse, 1858, p. 48; Hoffmann, Pringsheim's Jahrb., 1860, II, p. 273; Wolf, Braud des Getreides, 1874, p. 19; Same, Krankh. der landw. Nutzpflanzen, 1887, p. 53.

Here as in most other parts of the field no space of unused ground was left between the varieties. A careful examination of all plots when the wheat was in the shock revealed no smut except in the Fultz variety, which had less than five per cent. If there had been any spreading of the smut after the wheat was sown, it would certainly have been evident in the narrow strip of Velvet Chaff, unless we are to assume that this is not a susceptible variety, for it certainly showed no trace of smut.

The answer to the second question is even more direct and emphatic. Any trace of smut in the seed grain will produce an enormously greater amount in the crop. It takes but a single spore to infect, and consequently destroy the grain in the heads of a whole stool of two to six stalks; and in a single smutted kernel there are several million spores. One crushed kernel thoroughly distributed through a bin of seed wheat may result in many dollars loss when the crop is harvested, and any considerable amount of smut in the seed would effectually dissipate the profit, if it did not quite make the crop a failure.

There is a good experiment recorded bearing directly upon this part of the subject, made over a century ago. It is particularly interesting as being the first attempt, so far as known, to test the method of infection experimentally. It was made in southern Germany by Gleichen* in 1781, and is well worth repeating in this connection. He took two varieties of winter wheat and one of spring wheat. A part of each was soaked in water and then rolled in the dust from crushed grains of stinking smut until quite black; one lot was rolled in the smut without previously wetting, a part was soaked in pure water and sowed wet without adding smut, and a part was sowed dry without smut. The result is as follows:

		Good Heads.	Smutted Heads.	Per Cent of Loss.
1	Bearded wheat sowed wet with smut	178	166	48.
	" " " wet without smut	340	3	.8
	" " " dry " "	300	3	.9
2	" " " wet with smut	40	59	59.5
	" " " dry " "	102	35	25.5
	" " " dry without smut	89	1	1.1
3	Smooth " " wet with smut	48	14	22.6
	" " " dry without smut	82	9	9.9
	" " " wet " "	106	5	4.5
4	Spring " " wet with smut	339	188	35.6
	" " " wet without smut	198	4	1.9
	" " " dry " "	102	0	0

In the first group of three trials the smut was taken from bearded wheat; in the second and third from smooth wheat, and in

* L. c., p. 111.

the fourth from spring wheat. It is impossible to tell from the record how the accidental infection of the wheat sowed without smut took place, but the increase of smut when foul seed was used is very marked, being a total loss in the product from all trials of 37 per cent., while all trials with pure seed gave 2 per cent. of loss.

A possible contamination of seed grain, although the crop from which it was obtained may have been free from smut at the time of harvest, can come from the thresher having last been in a field of smutted wheat. It should be used for rye, barley or oats before passing from smutted to clean wheat. These cereals are never affected by stinking smut. In the same way clean seed may be contaminated by being stored in a bin, or passing through a fanning mill or seeder that has not been properly cleaned after being used for smutted wheat. Sacks also distribute the smut, and should be washed with soap and boiled, or at least turned and thoroughly beaten. Where possible a strong solution of blue vitriol should be used to disinfect with.

The experiments by Brefeld, cited above, show that the spores of stinking smut are particularly well adapted to preservation in an active state in manure. If the manure is moist enough for them to grow, they will not start and then perish because no wheat plant is near to be entered, but by absorbing nourishment will continue to grow like a mold and produce secondary spores, which in turn may or may not sprout at once, according to the amount of moisture into which they fall, and so on. It has been proven in the case of corn smut that the spores may pass through animals and retain their germinating power, and the same is likely true of wheat smut. The straw or grain from a smutted crop when fed to cattle may consequently have the larger part of the spores left in the droppings still possessing full vitality. Obviously the spreading of such spore-laden manure on a wheat field would be poor policy; let it be applied to some other crop instead.

This leads us to consider the question of how long the spores retain their power of germination. Is it safe, so far as stinking smut is concerned, to follow a crop of smutted wheat with wheat again if pure seed is used; if not, how long must one wait? The spores retain their power of germination when kept dry for two or three years, or even much longer*, but such conditions do not occur in the field, and we may doubtless safely assume that a field which is put into some other crop for one year will have but little or no smut in the wheat of the following year contracted from the last crop, and that two intervening years without wheat will practically eliminate every trace of it.

Natural Checks to Increase: It may seem strange that a disease like this does not continue to increase and spread when once

* Plowright, l. c., p. 87.

introduced into a region until profitable wheat growing is impossible. As a matter of fact, however, the conditions for the parasite are not so uniformly favorable that it can invariably show annual increase. One is reminded that "there's many a slip betwixt cup and lip" when considering such an experiment as that made by Gleichen. He blackened the moist wheat kernels with smut spores, and yet not quite half the resulting plants became infected. If one looks at the matter a little more carefully, however, the fact will not seem so strange. The spores are very small. If 300 of them are placed in a row they will hardly extend a quarter of an inch. A spore can reach in germination a distance of only about ten times its diameter, as one can judge from fig. 5; hence a spore lying a quarter inch away from the germinating plantlet is thirty times too far to ever reach it by direct growth. A grain of wheat is about a quarter of an inch long, so that only those spores which adhere near the germ end of the kernel are likely to effect an entrance into the growing plant.

The knocking about that every kernel is subjected to between the time of harvest and seeding, the friction and the winnowing, must altogether, while it distributes the smut more uniformly through the seed, also tend to leave only a minimum number of spores attached to each kernel. Seed grain containing so large a proportion of smut as to appear very unclean would, under most circumstances, be discarded, or else put through a fanning mill, and part of the spores removed. Thus thoroughly bad wheat is almost never sown.

Moisture and temperature are two important elements. A dry season is thought to decrease the stinking smut and a wet one to favor it, but on this point but little data can be found. A cold, wet time, just after seeding, however, is much more favorable to the growth of the smut than of the wheat, and a larger per cent. of smutted grain than usual is the result. A well-drained soil is therefore to some extent a protection against smut. It must be borne in mind however, that when the infected plants are once well started, a season or soil sufficiently dry to check the growth of the wheat does not interfere with the development of the fungus in the same ratio, as the latter draws its moisture from the juices of the plant, thus the smut may appear more luxuriant on dry soil or in a dry season than under moister conditions. But fuller data are much needed on this part of the subject.

The variety of wheat also makes a difference. At the Haw Patch all the considerably affected fields were Fultz wheat, a variety that has been grown in that region for many years, and in some other sections of the State as well. Muck wheat, a hardy local variety, and Velvet Chaff, both considerably grown, were little or not at all affected. I can find no published data on this point,

but there is no doubt that there is much difference in the susceptibility of different varieties, and that Fultz is among the most susceptible.

Nature of the Injury: Of course primarily and chiefly there is a definite percentage of the crop actually lost. The seed has grown, the heads have matured, but instead of good sound wheat, a certain part of the crop has only kernels filled with a black, unctuous powder. After harvesting and threshing, an extra amount of cleaning and screening must be gone through with to have the remaining wheat in a marketable condition, if one has the conscience to market it all.

The wheat is absolutely unfit for seed until put through a good fanning mill with extra precautions, and afterwards treated with blue vitriol or some other fungicide.

The flour from it is affected in proportion to the amount of smut. The best mills are now able to remove a large part of the smutted kernels; but as they are very fragile and the powder is greasy, many kernels break, and the powder is smeared over the good grains or mixed directly with the flour. The smut gives the flour a dark color and disagreeable smell, and also interferes with its proper action in various cooking processes, especially in bread-making.

Eating smutted flour is not recognized as at all detrimental to health. It is known however, that smut contains some of the same or a similar principle which makes ergot, or spurred rye, so powerful a medicine and so harmful when eaten. But probably enough smut in the flour to make it decidedly dangerous, would always be refused in food from its dark color and bad odor.

The straw and screenings from a smutted crop if fed to stock, used as bedding in stalls, or in any way converted into manure, are liable to spread the disease when used as a fertilizer upon wheat land.

Remedies and Precautions: There is no fungous disease known which can be so readily and absolutely prevented as stinking smut. It costs not a fraction of the trouble or expense that it does to remove the Colorado beetle from potato vines. Any farmer who will tolerate the smut pest in his fields after knowing how to control it, would doubtless let Canada thistles grow in his front yard.

Those who have read the foregoing account of the habits of the parasite will not need to be told that, after the grain is sown and the plants are infected nothing can be done to save the crop that follows from whatever loss may already be in store for it. All effort must be directed toward preventing loss in the next and succeeding crops.

Bessey* writes emphatically and to the point: "It has been demonstrated over and over again that perfectly clean seed and clean ground will produce a clean crop. It is with smut as with weeds of all sorts, if we have seeds we shall have weeds growing up as a result, but if we have no seeds there will be no weeds. So with smut. Clean seed upon a clean field will result in a clean crop."

To have a clean field wheat must not follow a crop of smutted wheat for one, or better yet, for two or three years. This advice is only needed by those who have not learned the advantages of a proper rotation of crops. And further, let no manure with straw from smutted grain mixed with it, or from stock fed on smutty straw or grain be spread on fields intended for wheat within a year or so of seeding.

To protect the sown seed from spores brought from a distance by wind or rain, be sure that it is well drilled in, so that every grain is covered with soil. The land is to be properly drained, so that the soil may not be too wet when the seed is germinating or when the plantlet is starting after the winter's rest, for in such cases the parasite gains time for growth while the plantlet is held in check. Sowing the seed during a cold wet time is also for the same reason a bad practice.

There are two ways of securing clean seed; either obtain it from a source of known purity, or treat it with a proper fungicide just before sowing by which the smut spores will be destroyed. Both methods have their advantages, and it will depend upon local circumstances as to which is to be preferred.

Various fungicides for this purpose are in use. Solutions of both salt and lime have been used for more than a century, more recently alum, lye from wood ashes, permanganate of potash, copperas, arsenic, saltpetre, dilute sulphuric acid, fresh cattle urine, and soap, have been tried. Most of these have some value, but there is yet another one so superior to them all that we need not stop to discuss those already named. This fungicide is sulphate of copper, commonly known as blue stone or blue vitriol. Like many other good remedies, its virtues have been known some time: Prevost, at the beginning of the century, dusted smut over wheat, then treated part with blue vitriol and sowed part without treatment. The treated gave 1 smutted head to every 4,000 heads, the untreated 1 to every 3 heads.

The manner of application of this remedy varies greatly. English and German agriculturists use dilute solutions, soaking the seed for several hours; the common practice being to cover the seed with a half per cent. solution for from 12 to 16 hours. The American method is to use stronger solutions and immerse the seed a shorter time.

* L. c., p. 122.

The Station has not as yet had opportunity to experiment in this line; without doubt, however, the following methods will be found safe and reasonably successful.

Where wheat is grown on a large scale, the solution is used in large quantities, of about the strength of half saturation, in a large tub, say a hogshead sawed in two. The wheat in sacks or bas kets is lowered into this solution until entirely wet. It is then removed, the surplus moisture allowed to drain off, and the grain thrown into a pile or left standing until the next day before sowing, that it may be in better condition for use.*

On the Pacific coast farmers use six pounds of copper sulphate to each ton of seed wheat. It is dissolved in sufficient water to wet this quantity of seed. The wheat is put into bags, say from 50 to 60 pounds each, and immersed for 6 or 7 minutes, just sufficient to thoroughly wet the wheat It is then taken out and laid on sloping boards at the end of the trough to drain—the trough used being made for the purpose, something like a horse-trough.†

Prof. E. W. Hilgard‡ recommends that the solution be as strong as it can be made at the ordinary temperature. Such a solution will contain about three pounds of the sulphate to five quarts of water. The time for immersion should be at least three minutes, during which the sack containing the grain should be turned several times to insure a thorough wetting of the contents.

Director Scovell§ of the Kentucky Experiment Station finding smut among the wheats of the Station had all the seed treated to prevent a recurrence. His method of applying the solution was as follows:—Ten pounds of blue vitriol were dissolved in eight gallons of water, the seed was turned loose into the solution and well stirred, care being taken that all the grain be immersed. The floating grains and particles were skimmed off and the solution poured into a tub, and reused whenever other wheat was to be treated.

Prof. I. P. Roberts of the Cornell Station while connected with the Agricultural College of Iowa, where this smut is often very troublesome, treated the seed to a solution of blue vitriol, using three pounds to five gallons of water. The wheat was made thoroughly wet with the solution. To dry the grain again land plaster or slacked lime was dusted over the pile, these being added and mixed with the wheat until the kernels no longer adhered to each other, when it was immediately sown like ordinary seed.

This treatment in its varying details aims at destroying the spores of the smut without injuring the germinating power of the

*Prof. W. H. Brewer, Report on Cereals, 10th U. S. Census, Agriculture, p. 461. The smut here referred to is the stinking smut 'Tilletia', although erroneously said to be an Ustilago or black smut.

† Hon. Horace Davis, U. S. Dept. of Agric., Report 1887, p. 388.

‡ U. S. Dept. of Agric., Report 1887, p. 388.

§ Bulletin No. 11, September 1887, p. 14.

wheat. Using a strong solution and soaking a short time save both time and trouble, but also require greater caution to avoid injury to the grain. While the seed is in the solution, which should more than cover it, it is well to stir the grain about and skim off all that floats, as in this way many unbroken smutted kernels are removed.

The grain can be sown by hand in a few hours after treatment, and if spread and stirred is ready for the drill in twenty-four hours. The drying can be accelerated, and according to many farmers with much improvement to the resulting crop, by dusting the grain with plaster or dry slacked lime, which absorbs the moisture and keeps the kernels from adhering to one another. More seed by measure must always be used per acre after treatment, as the grain has swollen somewhat by absorption of moisture.

This treatment with blue vitriol is not expensive, blue vitriol costing from seven to ten cents a pound, and is not so troublesome in application as it may seem to one unaccustomed to it. Its efficacy is beyond all question. In California "in early times," says Mr. Davis, in connection with the statement already mentioned, "we were much troubled with smutty wheat, but have little now, owing to the use of blue stone on the seed by many farmers." Prof. Scovell says that the treatment mentioned above "proved entirely successful, not the least smut appearing in any of the plots where the seed had been treated in this way, while the plot planted for comparison, without treating the seed wheat, contained about the same amount of smut as last year." Similar testimony has been given less succinctly by a number of writers. In Europe the practice is common, and in this country it will undoubtedly be more often profitably employed when its advantages are fully known.

The use of a strong solution of blue vitriol to disinfect the bin and machinery used for seed wheat cannot be too strongly urged.

Dipping seed grain into hot water of 127° for five minutes is advocated by Jensen* of Denmark as equally efficient with the blue vitriol treatment. It is a remedy worth trying.

When a farm is once thoroughly rid of the pest, it is easily kept free by a little care.

BLACK SMUT.

The present opportunity is taken to call the attention of cultivators to the very general loss which annually occurs in grain crops by the presence of black smut. This smut is odorless, not very conspicuous in the field and does not show in the threshed grain. For these reasons a loss of even ten per cent. of the crop rarely attracts attention or comment. But those conversant with the real state of the case will agree that "clean seed upon a clean

*Journal Roy. Agric. Soc. of England, XLVIII., 1888, p. 414.

field" is quite as desirable from an economical standpoint in connection with black smut as with stinking smut, and nearly as easy to secure. The very fact that there is actully a large annual loss from this cause, almost unrecognized by the farmer, and yet a preventable one, makes it desirable to speak plainly.

Black smut attacks wheat, oats, barley and rye. As a rule the whole of each head and all the heads in a stool are destroyed. Exceptions occur where but part of a head is smutted, as shown in

FIG. 6. Head of oats partly affected with black smut (Ustilago segetum). Natural size. After W. G. Smith.

figure 6, which brings out clearly the difference in appearance between perfect and smutted oats just before ripening.

Stalks bearing smut do not grow as tall as healthy grain, and consequently, while individually conspicuous enough, are readily overlooked in the field. The smut not only attacks the kernel but

also the chaff, and more or less completely reduces the whole head to a black powder (fig. 7), which is in marked contrast with the effect produced by stinking smut (compare fig. 2). The head remains much dwarfed and contracted. By harvest time the spores have ripened and largely blown away, or been washed off by the rains, leaving little or nothing but the rigid extension of the main stalk, which formed the support of the kernels.

From this brief description in connection with the illustrations it is probable that every farmer will recognize the kind of smut referred to, and a more complete description may therefore be left for some other occasion. The scientific name of the fungus is *Ustilago segetum*, or according to some writers who follow older data, Ustilago carbo, from which those somewhat acquainted with the significance attached to plant names will see that this smut is not so closely related to stinking smut as one might suppose from external appearances. Nevertheless the habits of the two parasites are sufficiently alike so that having already described the one it is unnecessary to enter into a detailed account of the other in order to make clear how to control it.

FIG. 7. Head of wheat affected with black smut (Ustilago segetum). At the right are six spores much magnified. After Bessey.

There are two features in the life history materially different from that of stinking smut. One is that no H-form secondary spores, but only simple ones, are produced, and the other that the spores ripen into a dry powder, and are largely scattered before or during harvest. The former has no economical bearing, but the latter is related to the fact that this smut is more difficult to eradicate and keep out of a farm than the other.

The method to be used in order to free a farm or crop of black smut is essentially the same as that already given above, with only this addition, that oats and barley on account of the hulls, should be soaked in the blue vitriol solution longer. Plumb* found that using four ounces of blue vitriol to a gallon of water, oats immersed for 17½ hours before planting left nearly two per cent. of smut in the resulting crop, while soaking for 40 hours left none. It is probable that with this strength of solution soaking 24 hours will usually be sufficient, and making the solution four times as strong,

* Fifth Annual Report of N. Y. Agric. Exp. Station, Albany 1887, p. 128.

according to the best practice with wheat, the time might be reduced to an hour or two or possibly less.

The number of recorded experiments in treating seed for black smut is not large, and the opinion is held by some that it does not prove as uniformly successful as with the stinking smut,* but yet there is every reason to suppose that if all precautions are carefully considered which the difference in the habits of the two suggest, equally good results may be obtained. The necessity of soaking oats and barley longer than wheat has already been mentioned. The fact that the soil receives a larger spontaneous sowing of spores from the crop of grain last grown than in the case of stinking smut makes it necessary to be even more cautious about following a smutted crop with any kind of cereal for two years or more if possible; for it must be borne in mind that while stinking smut attacks only wheat, black smut is equally destructive to all the other cereals.

The above suggestions will seem more important if the cultivator can realize that it is a fact, proven by actual count† that the loss from black smut always greatly exceeds the estimates made by looking at the crop in the field and that the prevention of this considerable loss is reasonably easy and economical.

SUMMARY.

The foregoing account of stinking smut (known as bunt in England) may be summarized in the following paragraphs:

It is one of the most destructive diseases to which the wheat crop is subject, not that it deteriorates the total product, but it causes a complete loss of a part, not infrequently of half or more of the crop.

It probably occurs to some extent throughout wheat growing regions, but most prominently in Indiana, Iowa, and adjacent states, as well as in California and Europe.

It is caused by a fungus growing inside the wheat plant. There are two species of this fungus, differing only in microscopic characters: Tilletia tritici with rough spores and Tilletia fœtens with smooth spores. The latter is most common in the Mississippi valley.

Spores of the fungus, which are very nearly or quite in contact with the germ end of the wheat grain, or touching the young plantlet between its attachment to the seed and the first joint, can grow into the tender tissues of the plant as the seed sprouts, and drawing nourishment from the juices develop along with the wheat, and finally produce spores in the kernels. A single spore may thus cause all the heads of a stool of wheat to smut.

* Plowright speaks on this point at some length and considers the one a certain and the other an uncertain operation. British Ured. & Ustil., 1889, p. 102.

† See results obtained by Arthur, Third Annual Report N. Y. Agric. Exper. Station, 1884, p. 382 : and Plumb, Fifth Annual Report of same, 1886, p. 124.

The disease does not spread from plant to plant or from field to field, but the infection always takes place at the time the seed sprouts.

No remedy can be applied after the grain is sown, but the disease can be prevented by sowing clean seed in a clean soil and covering well.

If a farm is already infested, seed known to be pure can be obtained, or the smutty seed can be purified by thoroughly wetting with a solution of blue vitriol, using one pound or more to a gallon of water, and either sow damp or first dry with plaster or slacked lime.

Take care that the thresher, storage bin, fanning mill, seeder, sacks and everything else coming in contact with grain to be used as seed are thoroughly disinfected, if they have previously been used for smutty wheat.

Do not follow smutted wheat with wheat again for one, or better still, for two years, but with some other crop.

Do not apply stable manure or permit stock to run on land to be put into wheat, if smutty grain or straw has been used for feeding or bedding.

Where there is danger of infection do not sow wheat on wet or insufficiently drained land, and use a variety of wheat least affected by smut.

The cost and trouble of ridding a farm of stinking smut, and keeping it free, is very slight compared to the loss which is likely to result from inattention.

The statements just made regarding stinking smut apply equally well to black smut with the following exceptions:

Black smut is more common everywhere than the other, and causes a loss greater than is usually supposed, but which rarely reaches the large percentages of stinking smut.

It is caused by a fungus. *Ustilago segetum*, of similar habits to the other smut, but unlike that is not confined to wheat, but attacks other small grains as well.

The means of clearing a farm of black smut are essentially the same as for the other, but with the differences that wheat, oats, rye and barley are all susceptible to the disease, and cannot follow one another when clearing the soil of the spores, and that grain with hulls requires longer soaking with blue vitriol than hulless grain.

JOSEPH C. ARTHUR, *Botanist.*

LaFayette, Ind., Sept. 1, 1889.